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Effect of the turf colorant Transition HC on infection with *Microdochium nivale*, winter survival and spring recovery on a Scandinavian putting green

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Summary:

This report presents results from a field trial evaluating the effect of Transition HC on infection with *Microdochium nivale*, winter survival and spring recovery of a putting green with a turf cover of *Poa annua* at Bioforsk Landvik, 15 October 2012 – 5 June 2013

Sammendrag:

Rapporten viser resultater fra et forsøk med utprøving av fargestoffet Transition HC på angrep av *Microdochium nivale*, overvintring og vårvekst på en tunrappgreen på Bioforsk Landvik, 2012-2013.

Trygve S. Aamlid

Project leader

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1. Abstract

The effect of the turf colorant Transition HC from Becker Underwood Ltd. on infection of *Microdochium nivale*, winter survival and spring recovery was evaluated in a factorial experiment on a putting green with a turf cover of *Poa annua* at the Bioforsk Turfgrass Research Center Landvik, SE Norway (58°34'N, 8°52'E, 10 m a.s.l.), from 17 Oct. 2012 to 5 June 2013. Transition was tested alone and in combination with the fungicide Delaro SC 325 (active ingredients protioconazole and trifloxystrobin) which is an approved and commonly used fungicide on Norwegian golf courses. Transition was applied at a rate 2.5 L in 400 L water per ha on 1 Nov. 2012, i.e. just after the last mowing in autumn, and again on 10 April, i.e. shortly after snow melt. Delaro was applied at a rate of 1.0 L in 250 L water per ha at starting attack of *Microdochium nivale* on 17 Oct. 2012 and again on 16 Nov. 2012. The experimental green was covered with snow from 2 Dec. 2012. Around new year, the lower part of the snow cover was transformed into a 10 cm ice layer due to the combination of frozen soil and a mild spell with temperature above 0°C.

The application of the the turf colorant on 1 Nov. resulted in darker and a more intensely green turfgrass color before winter. By the last assessment before snow cover, Transition also significantly improved turfgrass overall impression, and it reduced visual symptoms of *M. nivale* on plots that were not treated with fungicide. The fungicide Delaro resulted in significant quality improvements that were, for the most parts, stronger than those caused by the Transition.

In spite of the fact that the ice cover was chopped and removed on 31 January, four weeks of ice encasement and/or low temperatures shortly after ice removal resulted in complete winter kill of *Poa annua* on all plots that had not been sprayed with Delaro. Most plots sprayed with Delaro stood out nicely green when the snow melted, but the color faded due to photobleaching, and turfgrass winter survival was not higher than 30% at the final assessment in late April. The color caused by the application of Transition on 1 Nov. was not detectable after snow melt, and Transition had no effect on winter survival or turfgrass overall impression in spring.

As an addition to the original protocol, the effect of a third application of Transition on 6 May was tested in conjunction with verticutting and reseeding on plots that has suffered 100% winterkill. During this phase, there was no significant effect of the turf colorant on either soil temperature at 1 cm depth or the speed of turfgrass recovery after winterkill. Regardless of use of Transition or not, *Poa annua* recovered quickly, primarily from the soil seed bank, but also due to reseeding of unspecified seed of *Poa annua*. By the last assessment on 5 June, the average turf cover was 82 % on plots that were all dead in spring vs. 93% on plots that had partial winter survival after use of Delaro.

In conclusion, the results with Transition obtained during this winter does not justify a general recommendation for use of the product on Scandinavian putting greens. Since it was unfortunate for the evaluation of the product that the winter conditions became so severe that that most of the experimental area died due to ice encasement, we recommend that the evaluation continues for another year, either on the same experimental green or on another green with a turf cover of *Agrostis stolonifera*.

2. Introduction

Winter survival is the foremost challenge in Scandinavian golf course. The turf colorant Transition HS from Becker Underwood Ltd. has been claimed not only to improve the color of dormant turf during the winter months, but also to protect from winter injuries and to promote green-up in spring. The most commonly cited reason for these positive effects is higher canopy temperatures and thus enhanced metabolism due to better interception of solar radiation. Such effects have been scientifically documented in the southern United States where turf colorants are sometimes considered an alternative to overseeding of warm season grasses (e.g. Kaufman et al. 2009; Briscoe et al. 2010), but, to the best of our knowledge, not at higher latitudes where light intensities are generally lower. As for winter protection, turf colorants are also claimed to reduce the risk for dehydration of turfgrass crowns (Oberle 2010).

In September 2012, the Bioforsk Turfgrass Research group signed a contract with Becker Underwood Ltd. to make a first evaluation of Transition in a green trial. It was agreed to test the performance of the colorant both when applied alone and in combination with a fungicide that is commonly used on Scandinavian golf courses.The research was carried on a *Poa annua* green at the Bioforsk Turfgrass Research Center Landvik, SE Norway (Photo 1).

Photo 1. Experimental Poa annua green at the Bioforsk Turfgrass Research Center Landvik, SE Norway. The front area (eastern part of the green) was used for the evaluation of Transition.

3. Materials and methods

3.1 Experimental site and maintenance until the start of experimentation

The experiment was carried out from 17 Oct. 2012 to 5 June 2013 on the eastern part of an experimental USGA-spec. green at Landvik on the Norwegian south coast (58°34'N, 8°52'E, 10 m a.s.l.). The green was constructed in Nov. 2004 with 12% (v/v) peat as organic amendment to the sand root zone. In spring 2011, it had been deturfed, 3 cm of new root zone material added (again with 12% (v/v) peat) and a new turf cover of *Poa annua* established, partly using plugs from Kjekstad golf course, Drammen, SE Norway, and partly unspecified seed of *Poa annua* from the Norwegian seed dealer Fellekjøpet Agri. Soil samples taken on 22 Oct. 2012 from the 20 cm topsoil layer indicated a pH(H_2O) of 6.1, an ignition loss of 1.3% and plant available contents of P, K, Ca and Mg of 2.2, 5.2, 14 and 2.2 mg (100 g dry soil)$^{-1}$, respectively. By the start of the trial on 17 Oct. 2012, the botanical compostition was 97% *Poa annua* and 3% *Agrostis capillaris*, and there was a starting attack of *Microdocium nivale* with visual symtoms on 5 % of the experimental area.

<u>Fertilization</u>

Fertilizer plans for 2012 are shown in Table 1. A combination of liquid (Arena Crystal, Arena Calcium, Greenmaster liquid) and solid products (Arena Green Plus, Arena Start, Greenmaster 14-0-10) was used.

Table 1. Fertilization of Poa annua *experimental green during 2012.*

		kg per 100 m^2								
Date	**Fertilizer type**	**Fertilizer**	**N**	**P**	**K**	**Mg**	**S**	**Ca**	**Fe**	**Mn**
20 Mar.	Arena Calcium	1.00	0.000	0.000	0.000	0.000	0.160	0.210	0.000	0.000
20 Mar.	Arena Crystal 19-2-15	0.60	0.114	0.011	0.090	0.014	0.022	0.000	0.001	0.000
11 Apr.	Arena Green Plus 10-1-10	1.50	0.150	0.012	0.150	0.008	0.116	0.000	0.015	0.006
27 Apr.	Arena Start 22-3-10	0.68	0.149	0.020	0.068	0.000	0.027	0.000	0.000	0.000
11 May	Arena Green Plus 10-1-10	1.95	0.195	0.016	0.195	0.010	0.150	0.000	0.020	0.008
22 May	Arena Start 22-3-10	1.00	0.220	0.030	0.100	0.000	0.040	0.000	0.000	0.000
6 Jun.	Arena Start 22-3-10	1.00	0.220	0.030	0.100	0.000	0.040	0.000	0.000	0.000
20 Jun.	Greenmaster liq. 10-0-10	2.80	0.280	0.000	0.230	0.000	0.000	0.000	0.000	0.000
3 Jul.	Arena Start 22-3-10	0.75	0.165	0.023	0.075	0.000	0.030	0.000	0.000	0.000
17 Jul.	Arena Green Plus 10-1-10	1.65	0.165	0.013	0.165	0.009	0.128	0.000	0.017	0.007
24 Jul.	Arena Green Plus 10-1-10	1.65	0.165	0.013	0.165	0.009	0.128	0.000	0.017	0.007
14 Aug.	Arena Start 22-3-10	0.60	0.132	0.018	0.060	0.000	0.024	0.000	0.000	0.000
29 Aug.	Arena Crystal 19-2-15	0.60	0.114	0.011	0.090	0.014	0.022	0.000	0.001	0.000
29 Aug.	Arena Calcium	0.75	0.000	0.000	0.000	0.000	0.120	0.158	0.000	0.000
11 Sep.	Arena Start 22-3-10	0.45	0.099	0.014	0.045	0.000	0.018	0.000	0.000	0.000
26 Sep.	Greenmaster 14-0-10	0.64	0.090	0.000	0.053	0.012	0.000	0.000	0.006	0.000
2 Oct.	Arena Crystal 19-2-15	0.50	0.095	0.010	0.075	0.012	0.019	0.000	0.001	0.000
9 Oct.	Arena Crystal 19-2-15	0.45	0.086	0.009	0.068	0.010	0.017	0.000	0.001	0.000
23 Oct.	Arena Crystal 19-2-15	0.40	0.076	0.008	0.060	0.009	0.015	0.000	0.001	0.000
7 Nov.	Arena Crystal 19-2-15	0.30	0.057	0.006	0.045	0.007	0.011	0.000	0.001	0.000
Sum			2.572	0.244	1.834	0.114	1.087	0.368	0.080	0.028

Mowing, verticutting, topdressing and wear treatments during 2012

During the growing season 2012 the green was cut with a single walk-behind green's mower every Monday, Wednesday and Friday and exposed to artificial wear using a friction wear roller with soft spikes for a total of 30 times corresponding to 10.000 rounds of golf. Mowing started at 9 mm on 26 March and was gradually lowered to the standard height of 3 mm on 18 May, at which it was maintained until late September. The mowing height was raised to 4 mm from 26 Sep. and to 5 mm at the last mowing on 31 Oct. 2012.

During the growing season, the green was also verticut four times and topdressed (dusted) 17 times corresponding to a total rate of 3.7 mm of pure sand (0.2-0.7 mm, no organic amendment).

Use of soil surfactant

Due to starting indications of soil water repellency, the experimental area was treated with Revolution (Aquatrols Inc., Paulsboro, NJ, USA) on 26 July (1.9 L ha^{-2}) and 6 August (2.5 L ha^{-2}) 2012.

3.2 Experimental plan and implementation

The two-factorial experiment was laid out according to a randomized complete four- block design on 17 Oct. 2012. The treatments were:

Factor 1: Turf colorant

1. No colorant
2. Transition HC, 2.5 L ha^{-1} after last mowing in October and shortly after snow melt in March / April, and - if necessary – in conjunction with verticutting / reseeding in spring.

Factor 2: Fungicide

A. No fungicide
B. Delaro SC 325, 1.0 L ha^{-1} at first sign of disease in October and again 3-4 weeks after first application

The fungicide Delaro SC 325 (Bayer Crop Science) contains 175 g a.i. protiozonazole and 150 g a.i. trifloxystrobin per liter.

The experimental field map is shown in Fig. 1.

Applications were conducted according to the Norwegian 'Good Experimental Practise' Protocol (Tørresen 2007). We used an experimental backpack plot sprayer (Oxford / LTI) working at 150-200 kPa pressure and with a 1 m wide boom with three nozzles (Teejet 11002) 50 cm apart. Screens on both sides of the boom prevented drift to neighbor plots. The procedure allowed full coverage of the central 1.0m x 1.0m of each plot which was used for later registrations. The spraying volume of Transition was 400 L ha^{-1} ha and of Delaro 250 L ha^{-1}. Actual application rates were recorded by weighing the tank before and after spraying. Details from the various application dates are given in Table 2.

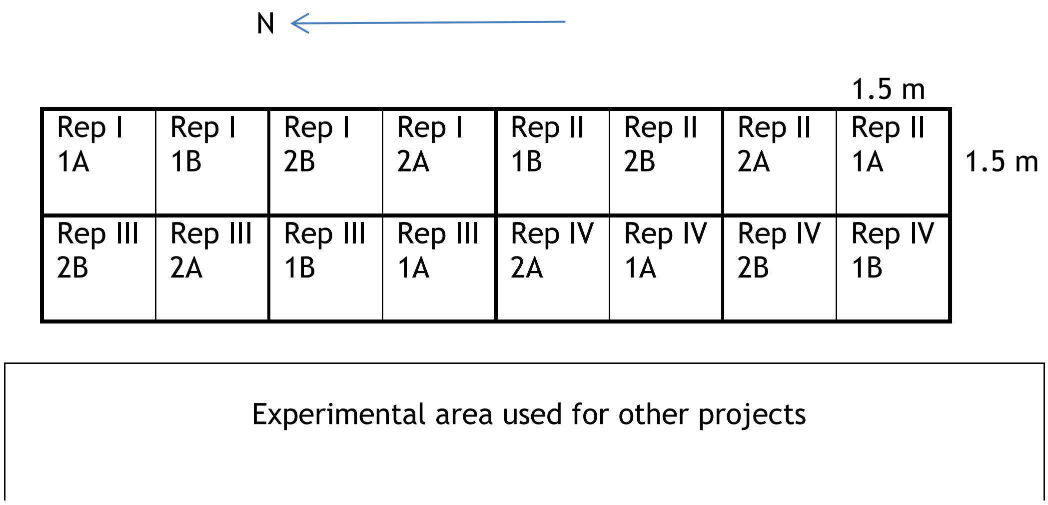

Figure 1. Field map of Transition trial.

Table 2. Application date and time of day, applied rates according to weighing before and after application, weather conditions at application and hours to first rainfall after application. Data from Landvik weather station.

Date	Spraying, time of day	Product applied	Target rate, L ha^{-1}	Realized rate, L ha^{-1}	Weather at application			Hours before rainfall
					Air temp. °C	Rel.humi -dity, %	Wind, m s^{-1}	
17 Oct. 2012	10:00-11:00	Delaro SC 325	1.00	1.19	6.9	97	0.4	9
01 Nov. 2012	10:30-11:30	Transition HC	2.50	2.62	8.5	81	1.7	5
16 Nov. 2012	10:30-11:30	Delaro SC 325	1.00	1.07	9.2	85	2.1	4
10 Apr. 2013	12:00-13:00	Transition HC	2.50	2.50	1.6	63	2.1	>12
06 May 2013	12:00-13:00	Transition HC	2.50	2.47	12.0	77	3.0	>12

3.3 Weather data and management during winter and spring

The average temperature for October 2012 was slightly lower, but the average for November 2012 higher than the 30 year normal value (Table 3). From 30 Nov. there was a sudden drop in temperature resulting in frost to almost 30 cm depth in the green root zone (Fig. 2). Three days later, on 2 Dec., we had approximately 20 cm of snow. December had an average temperature 3.5°C lower than the 30 year normal, and precipitation was very high, partly as snow and partly as rain. During the last week of the year there a long mild spell resulting in a 10 cm layer of ice on the green.

Table 2. Monthly values for temperature and precipitation at Landvik from 1 Sep. 2012 to 31 May 2013 and 30 year normal values (1961-1990).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Temperature, °C								
2012-2013	6.8	4.8	-3.3	-3.1	-2.1	-1.8	3.7	11.5
30 year normal	7.9	3.2	0.2	-1.6	-1.9	1.0	5.1	10.4
Precipitation, mm								
2012-2013	218	239	286	81	26	36	101	134
30 year normal	162	143	102	113	73	85	58	82

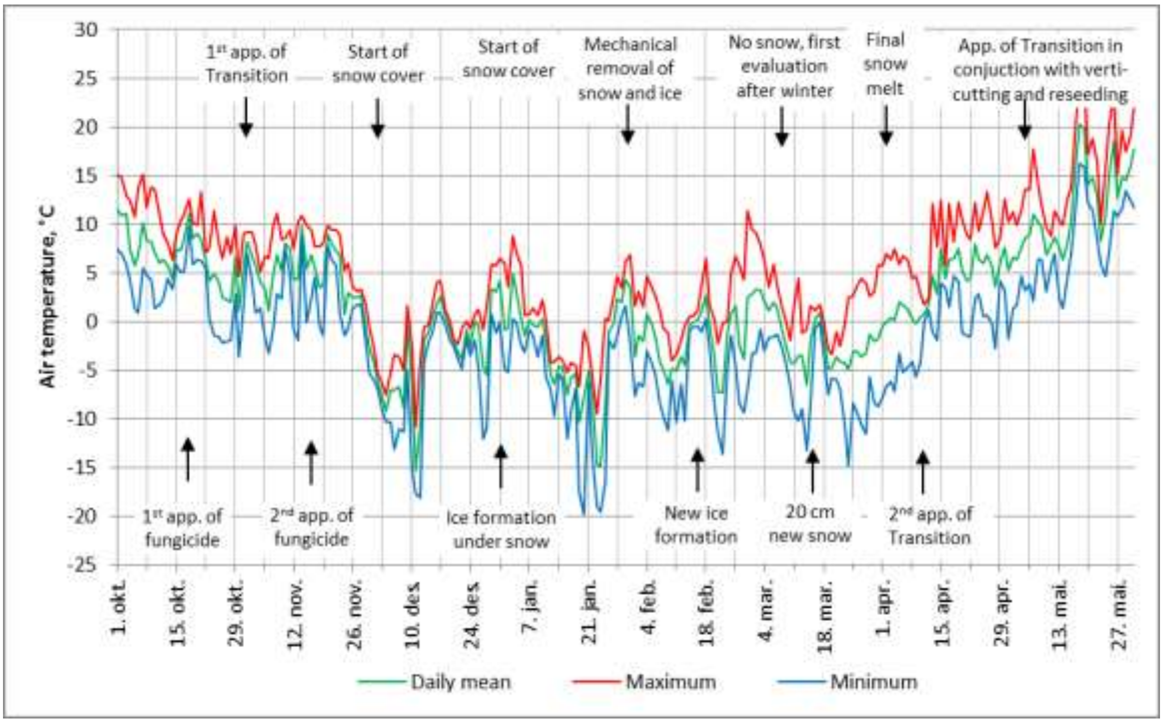

Figure 2. Official recordings of daily mean, maximum and minimum air temperatures at Landvik weather station from 1 Oct. 2012 to 1 June 2013 and major events in the field trial.

Based on earlier experiences showing poor tolerance to ice encasement in *Poa annua* (Aamlid et al. 2009, 2011) we decided to remove the ice from the experimental area as soon as possible. However, because of temperatures down to -20°C, there was no opportunity for ice removal until a mild period in the last week of January. At this stage, samples taken inside indicated that the turf was still alive. On 25 and 28 Jan. we were able to drive on the ice layer and remove 20-30 cm snow on the top of the ice layer (Photo 2). Then we dressed a thin layer of dark sand on the ice to enhance melting both from the top and from the bottom. Three days later there was a thin water film between the turf and the ice that allowed us to remove the ice without any damage to the turfgrass crown area (Photos 3-4). After ice removal on 31 Jan., the green was covered with an agryl tarp to protect the newly exposed turf from cold, as air temperatures the following night went down to -7.7°C. On 2 Feb., the weather forecast said snow, so we removed the tarp and the green was covered with 5-10 cm of light snow for the following two weeks.

Photo 2. Driving on the 10 cm thick ice layer to remove snow on 25 January. Photo: Trond Pettersen.

Photo 3. Mechnical removal of ice on 31 Jan.   Photo: Trond Pettersen.

Photo 4. After ice removal on 31 Jan. Experiment with Transition was located on the distant side of the green. Photo: Trond Pettersen.

In mid-February there was again a mild period causing ice to be formed on the green (Photo 5), but this only lasted for about two weeks. By this time, samples taken regularly into the growth chamber indicated that the turf was dead, at least in some of the plots.

In the first week of March the snow and ice had melted and the trial could be assessed for the first time after winter (Photo 6). From 15 March the green was again covered with snow until about 1 April. Both March and April were much colder than the 30 year normal values (Table 2), and when the spring application of Transition was made on 10 April, the green was only thawed in the upper 5 cm.

Photo 5. New formation of ice, 16 Feb. 2013. Photo: Trond Pettersen.

Photo 6. Ready for assessment during an intermittent period with no snow, 8 March 2013. Photo: Trygve S. Aamlid.

3.4 Management in spring

Although it was clear that many of the treatments had not survived the winter, Transition was applied according to protocol on 10 April 2013 (Table 2, Photo 7), and the experiment was fertilized for the first time on 23 April.

Photo 7. Spraying Transition on 10 April 2013. Photo: Anne A. Steensohn.

On 3 May 2013, after the last assessment of winter survival, the experiment was core-areated and verticut in both directions to stimulate recovery, mainly from the soil seed bank, but also by adding 5 g m^{-2} of unspecified *Poa annua* seed. After reseeding the experiment was topdressed with 2 mm of pure sand and covered with agryl tarp until 16 May. On 6 May, the tarp was removed and Transition sprayed on plots that had not been treated with the fungicide Delaro and therefore had not survived the winter. During the following period of recovery in May 2013, the experiment received weekly fertilizer application, partly liquid and partly granular formulation, the total amount being 0.79 kg N, 0.10 kg P and 0.65 kg K per 100 m2 (Table 3). The first mowing was accomplished to 7 mm on 16 May.At the final assessment on 5 June, mowing height was still at 6 mm.

Table 3. Fertilization of Poa annua *experimental green in spring 2013.*

		kg per 100 m^2								
Date	Fertilizer type	Fertilizer	kg N	kg P	kg K	kg Mg	kg S	kg Ca	kg Fe	kg Mn
Before verticutting /reseeding:										
23 Apr.	Andersson 13-2-13	1.00	0.130	0.009	0.108	0.000	0.183	0.000	0.0200	0.0010
After verticutting / reseeding:										
08 May	Wallco liquid	2.20	0.112	0.022	0.095	0.009	0.009	0.009	0.0004	0.0004
15 May	Arena Crystal (liquid)	1.20	0.228	0.023	0.180	0.028	0.044	0.000	0.0016	0.0006
21 May	Wallco liquid	4.40	0.224	0.044	0.189	0.018	0.018	0.018	0.0007	0.0009
28 May	Andersson 13-2-13	1.70	0.221	0.015	0.184	0.000	0.311	0.000	0.0340	0.0017
			0.785	0.104	0.648	0.055	0.382	0.027	0.0367	0.0036

3.5 Registrations and statistical analyses

- Per cent of plot area infected with *Microdochium nivale* was recorded at two to three week intervals in the fall and on 30 April in spring. The spring assessment only included plots that were not completely killed by ice encasement.
- Turfgrass color was assessed on 16 Nov. 2012, on 8 March 2012 (during the short period without snow cover), and on two occasions in April. On 16 Nov. we evaluated two different aspects of color, i.e. 'darkness' (1-9, 9 is darkest turf) and 'color intensity/freshness' (1-9, 9 is most freshly green/highest intensity). In March and April we only recorded the intensity aspect.
- Turfgrass overall impression (1-9, 9 is best quality, 5 is acceptable) was recorded at two to three week intervals from the start of experimentation on 17 Oct. until snow cover on 2 Dec. and from snow melt around 1 April until verticutting/ reseeding in early May.
- Per cent coverage was recorded at approximately weekly intervals during the last phase of the project, i.e. from verticutting / reseeding until the final registration on 5 June.
- Soil temperature was measured with a hand-held probe at 1 cm depth in each plot for total of eleven times during the course of the trial; two in the fall, five before verticutting /reseeding in spring and four after verticutting/reseeding in spring.

All experimental data were analysed using the SAS procedure PROC ANOVA. In tables and figures, significance levels in the ranges <0.001, 0.001-0.01, 0.01-0.05, 0.05-0.1 and >0.1 have been indicated by ***, **, *, (*), and ns, respectively. The term 'significant' in the text always refer to $P<0.05$, whereas P-values in the range 0.05-0.10 have been referred to as 'tendencies'.

4. Results

4.1 Assessments before winter

4.1.1 Infection with Microdochium nivale

Microdocium patches covered approximately 5 % of plot area at the first application of fungicide on 17 October. Following observations always indicated a significant effect of Delaro on the development of the fungus. When assessed on 16 and 23 Nov., i.e. approximately two and three weeks after application, Transition also caused a significant reduction in per cent of plot affected by disease. At the last observation before winter on 23 Nov. there was a significant interaction in that Transition reduced *Microdochium nivale* only on plots that had not been treated with fungicide (Fig. 3).

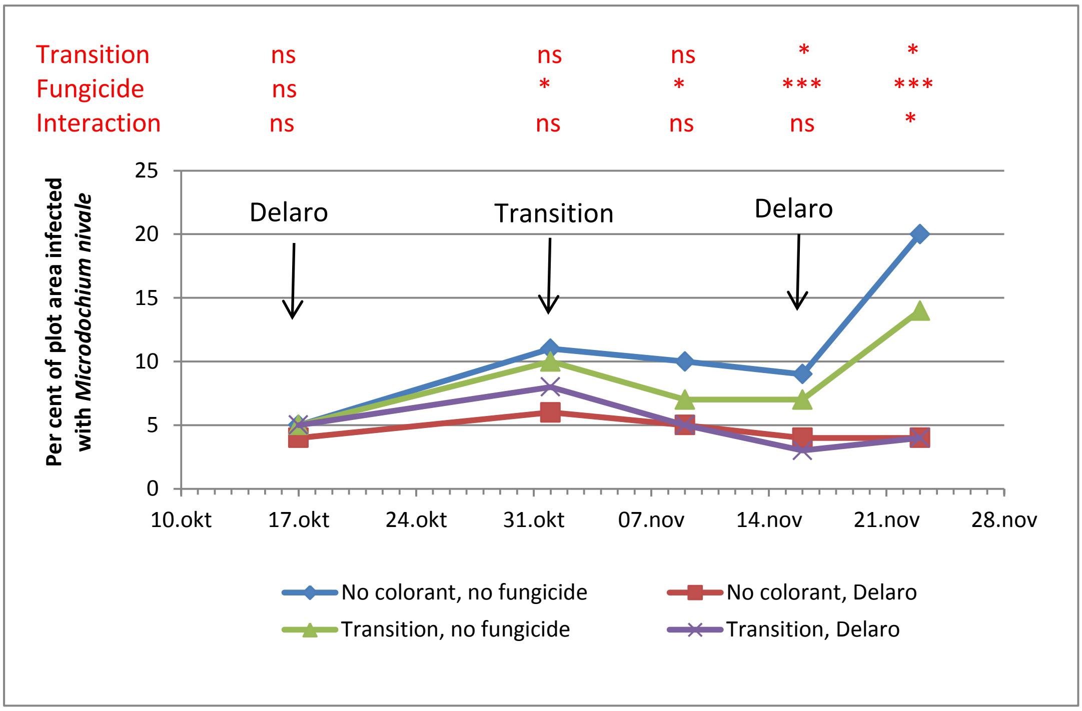

Figure 3. Effect of the colorant Transition and the fungicide Delaro on infection with Microdochium nivale *in autumn 2012. Application dates have been indicated.*

4.1.2 Turfgrass color

Both Transition and Delaro had significant effects on turfgrass color before winter (Table 4, Photos 8-11). Transition affected both darkness of green and color intensity (green vs. faded/dormant), whilst the effect of Delaro was significant for color intensity only. The highest score for color intensity was recorded on plots treated with both products (interaction almost significant; Figure 4).

Table 4. *Main effect of the colorant Transition and the fungicide Delaro on two aspects of turfgrass color evaluated on 16 Nov. 2012.*

Main effect	Darkness of green (1-9, 9 is most dark)	Color intensity (1-9, 9 is most intense)
No colorant	6.6	4.6
Transition	7.4	5.8
Sign.	*	***
No fungicide	6.8	4.5
Delaro	7.3	5.9
Sign.	(*)	***
Interaction	ns	(*)

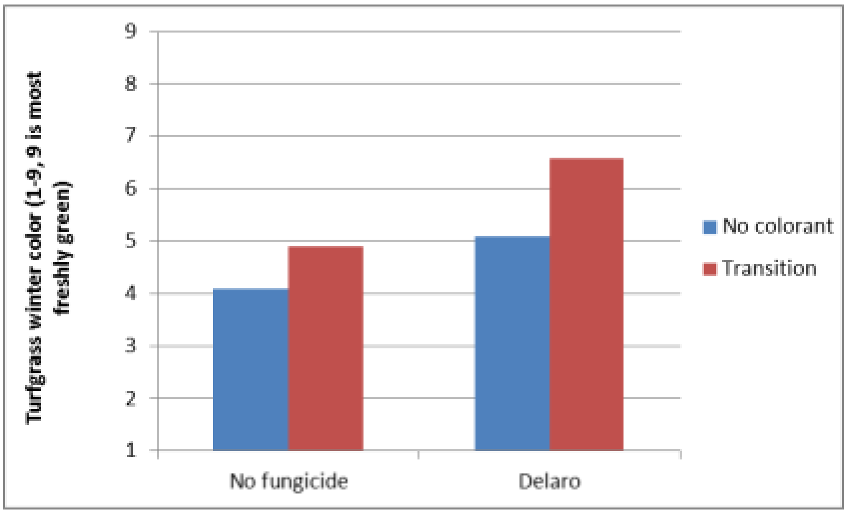

Figure 4. Tendency (P=0.057) to interaction between fungicide and colorant on turfgrass color intensity / freshness on 16 Nov. 2012.

4.1.3 Turfgrass overall impression

The experimental area was very uniform with no major difference in turfgrass overall impression at the start of experimentation on 17 Oct. 2012 (Table 5). During the following weeks, the scores for overall impression were influenced mainly by disease, but also by turfgrass color.

The first application of Delaro on 17 Oct. caused a significant improvement in overall impression and this effect was strengthened by the second application on 16 Nov. At the last assessment before winter there was also a significant improvement in overall impression due to the application of Transition on 1 Nov., although this effect was stronger for plots not treated with fungicide than for plots treated with Delaro (Fig. 5).

Table 5. Main effect of the colorant Transition and the fungicide Delaro on turfgrass overall impression in autumn 2012. The first applications of Delaro and Transition were made on 17 Oct. and 1 Nov., respectively.

	Turfgrass overall impression (1-9, 9 is best turf)		
	17 Oct.	1 Nov.	23 Nov.
No colorant	4.9	4.6	4.9
Transition	4.9	4.7	5.8
	ns	ns	**
No fungicide	4.8	4.1	3.8
Delaro	4.9	5.2	6.9
	ns	*	***
Interaction	ns	ns	(*)

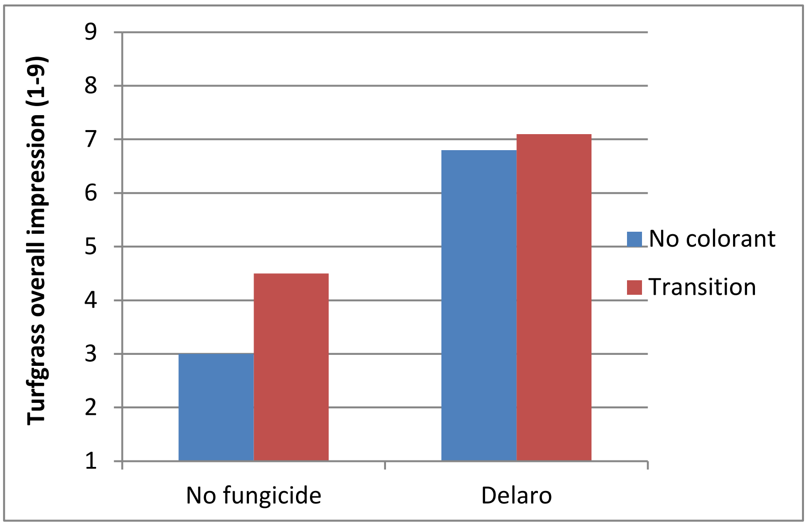

Figure 5. Tendency (P=0.062) to interaction between fungicide and colorant on turfgrass overall impression on 23 Nov. 2012 (last evaluation before winter).

Photo 8. Part of the trial just after application of Transition on 1 Nov. 2012. The dark green stripes along edges of plots sprayed with Transition were due to the screen used on each side of the spraying boom (see also photo 7). Red spots indicate treatment (gross) plots, while blue spots indicate area used for assessment. Photo: Trond Pettersen

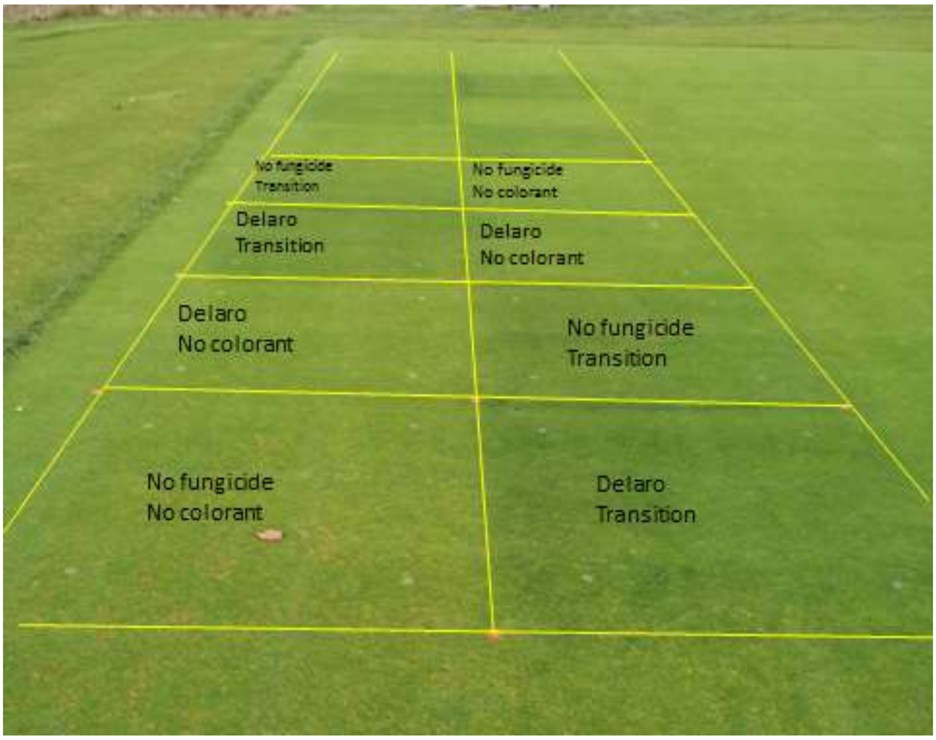

Photo 9. Trial photographed from the northern side just after application on 1 Nov. 2012. Photo: Trond Pettersen

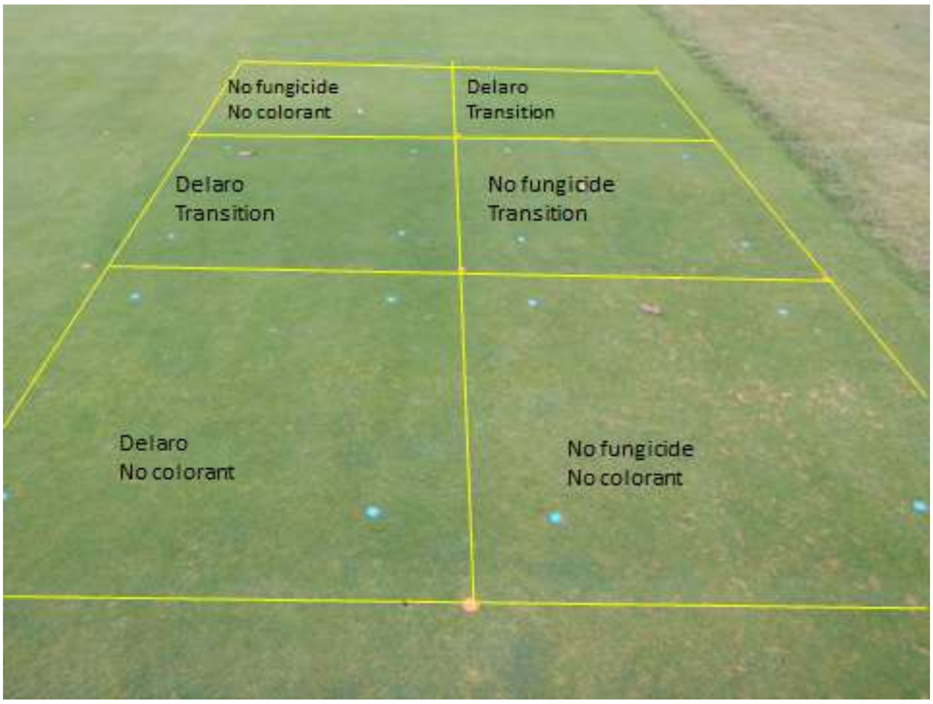

Photo 10. Trial photographed from the southern side on assessment on 16 Nov. 2012.
Photo: Trond Pettersen

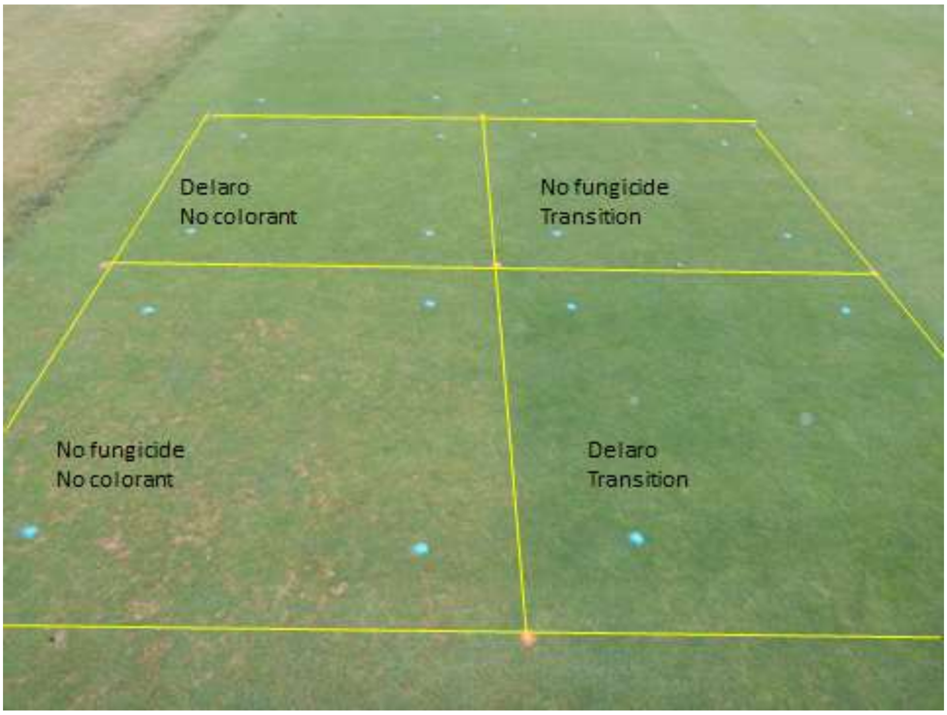

Photo 11. Trial photographed from southern side on assessment on 16 Nov. 2012.
Photo: Trond Pettersen

4.2 Assessments before reseeding in spring

Assessment during the intermittent period with no snow cover in early March showed a significant effect of Delaro, but not of Transition, on color intensity/freshness (Table 6, Photo 12). One month later, these results were confirmed by the assessment taken just after the final snow melt in early April (Photos 13 and 14).

The fact that the color intensity declined from the first assessment just after snow melt until the assessment on 30 April reflects that many of the plots were dead after winter, but also the photobleaching / photoinhibition that occurred when surviving turf was exposed to strong light after snow melt. The application of Transition on 10 April tended to prevent the decline in color intensity from 8 April to 30 April on plots that were partly alive after use of fungicide, but the color effect was not significant and not reflected in turfgrass overall impression (data not shown).

Table 6. Main effect of the colorant Transition and the fungicide Delaro on turfgrass color intensity (freshness), overall impression, per cent winter survival and per cent of plot area affected by MIcrodochium nivale *in spring 2013.*

	Turfgrass color intensity (1-9, 9 is most intense)			Overall impression (1-9), 9 is best turf		% coverage of surviving, undiseased turf		*M.nivale*, % of plot area[1]
	08 Mar.	08 Apr.	30 Apr.	20 Apr.	30 Apr.	22 Apr.	30	30 Apr.
No colorant	3.4	3.6	2.5	2.0	1.4	21	17	9
Transition	3.6	3.0	2.8	2.3	1.4	26	13	5
Sign.	ns	ns	ns	ns	ns	ns	ns	*
No fungicide	1.9	2.1	1.0	1.2	1.0	1	0	-
Delaro	5.1	4.5	4.3	3.1	1.8	46	30	-
Sign.	***	***	**	*	*	**	*	-
Interaction	ns	ns	ns	ns	ns	ns	ns	-

[1] Evaluated only on plots sprayed with Delaro.

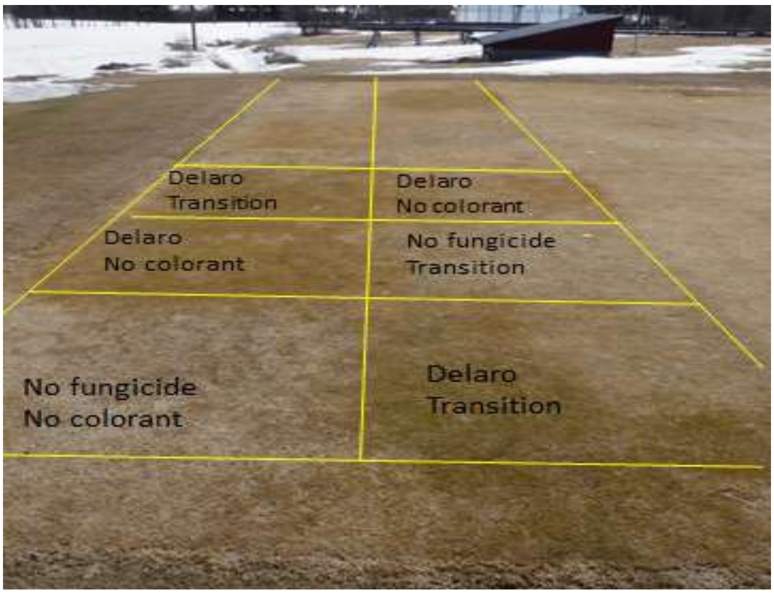

Photo 12. Turfgrass color at assessment on 8 March 2013. Photo: Trygve S. Aamlid

Photo 13. Plots on northern side of experimental area on 8 April. Photo: Trygve S. Aamlid

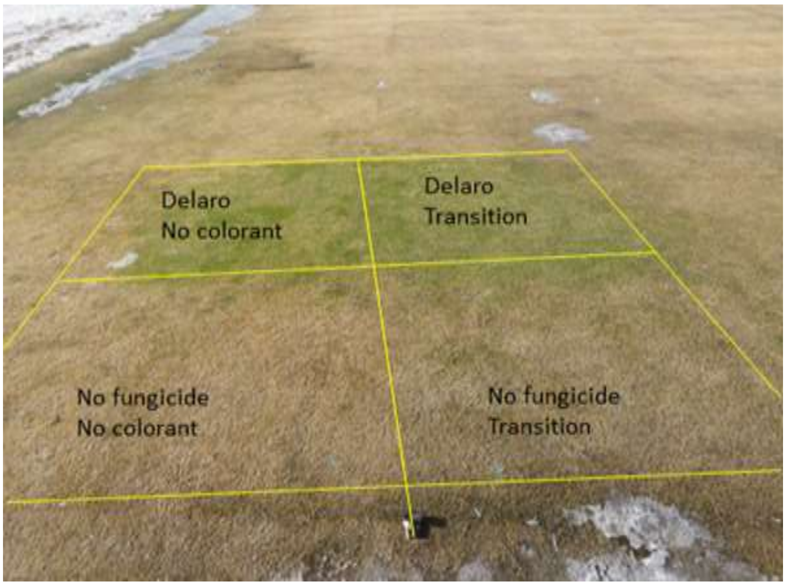

Photo 14. Plots on southern side of experimental area on 8 April. Photo: Trygve S. Aamlid

Photo 15. Visual impression on 30 April, twenty days after spring application of Transition. Photo: Trygve S. Aamlid

At both assessments in April, turfgrass overall impression higher on plots treated with Delaro than on plots not sprayed with fungicide (Table 6, Photos 13-14). The last assessment on 30 April showed that 30% of the *Poa annua* had survived on plots treated with Delaro vs. no survival on unsprayed plots (Photo 15). The turf colorant had no effect on overall winter survival, but assessment on the plots that had been treated with Delaro showed an effect of Transition on per cent of plot area with visual symptoms of *Microdochium nivale* (Table 6).

4.3 Turfgrass recovery after verticutting in spring

Poa annua soon started to regenerate new turf cover in response to aeration, verticutting and reseeding on 3 May. At the final assessment on 5 June, there was only a 10 per cent unit difference in turf cover between plots that had been completely dead after winter and plots with a certain survival after application of fungicide. Application of Transition on 6 May had no effect on spring recovery.

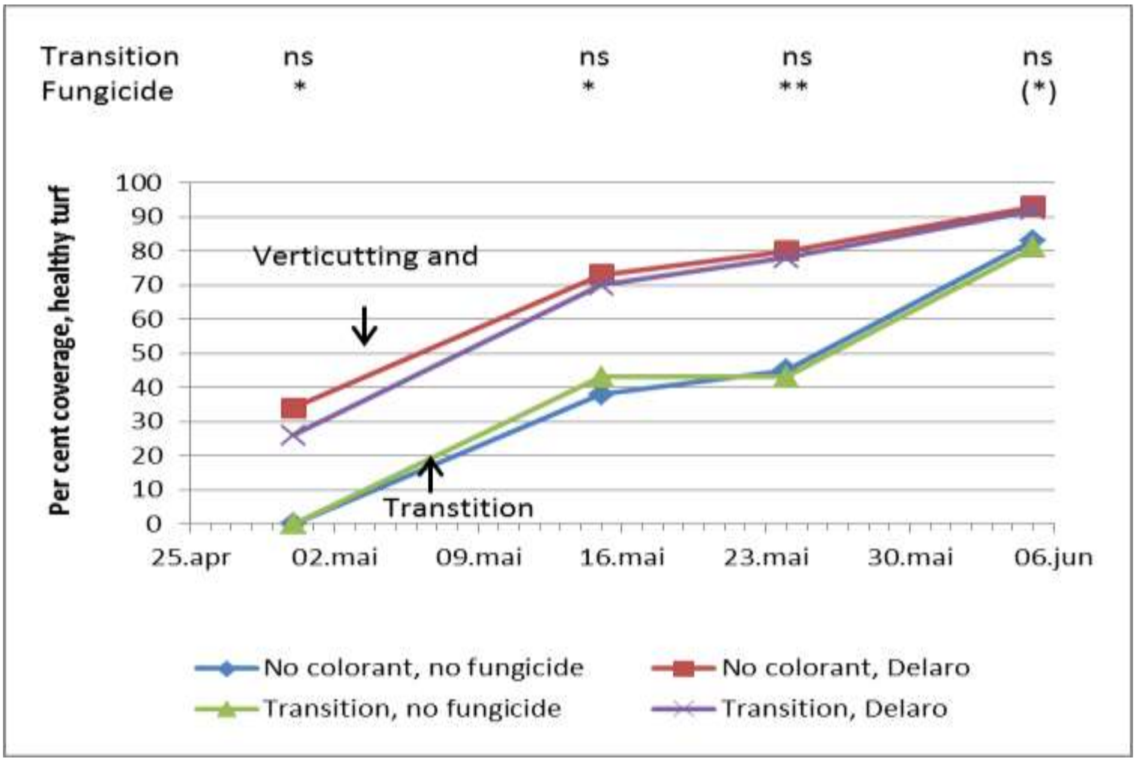

Figure 6. Per cent turf cover during reestablishment in spring 2013.

4.4 Soil temperatures

Mean values of eleven measurements from 16 Nov to 27 May showed no effect of Transition on soil temperature. Mean values were 11.9°C on both plots with and without colorant. Among individual measurements Transition raised soil temperature significantly only on 30 April, when the mean values were 14.6 and 14.2 °C for treated and non-treated plots, respectively.

5. Discussion

In this trial, the turf colorant Transition had hardly any effect on soil temperature at 1 cm depth. Although temperature, measured just below crown level, may well have been different from canopy temperature, the lack of significant differences between treated and untreated plots probably reflects the lower level of incoming radiation in Scandinavia (55-71°N) compared with areas further south, especially in the late fall. In a comparison of various turf colorants in Arizona, USA (32°N), the increase in surface temperature in November was at the most 1.3°C (Whitlark & Umeda 2012), and in a trial in Tennessee, USA, (35°N), Kaufman et al. (2009) found a significant effect of colorants on canopy temperature only on the most sunny days.

One important aspect of a turf colorant is its persistence or longevity. Differences in longevity among turf colorants on the American market were documented by Whitlark & Umeda (2012) and Miller (2011), and we have also, in a different project, tested a combined fungicide and colorant with a more durable effect than of Transition in the present trial. One reason why the color of Transition was not detectable after snow melt in March might be unstable winter with ice cover, periods with melting water and especially the ice removal on 31 January.

As documented by Miller (2011) and Whitlark & Umeda (2012), chances of having a positive effect of a turf colorant are usually better if the turf has a natural background color than if it is completely dormant or brown at the time of application. In the present trial, we certainly could not expect any effect of the spring application of Transition on the turf that was dead after winter. On the other hand, the application to plots with a certain winter survival could perhaps be expected to protect the turf from UV radiation and result in less photoinhibition. Ervin et al. 2007) documented such an effect of a turf colorant in American experiments with Kentucky bluegrass, but the effect was not significant in our trial.

The most positive effects of Transition in this trial were the enhancement on turf color and overall impression in the fall. These effects were also accompanied with a reduction in per cent of plot area infected by microdochium patch. It is not possible to tell from the present data if the reduction in *Microdochium nivale* was a true effect on disease development or if it was only due to disease symptoms being masked by the colorant. We have not been able to find in the literature any documentation for a physiological effect of turf colorants on disease development.

The effect of Delaro on winter survival of *Poa annua* was remarkable in light of the fact that *Microdochium nivale* requires oxygen and therefore normally does not develop under ice cover. In other words, it appears that the fungicide had a physiological effect that made the turf more tolerant to ice encasement, e.g. by inhibiting degradation of chorophyll and thus enhancing photosynthesis during the hardening phase in late October and November. A plant growth-regulating effect of DMI-fungicides was early documented in studies with Kentucky bluegrass, (Kane & Smiley 1983) and recent findings in creeping bentgrass suggest that DMI fungicides, (e.g. protioconazole in Delaro) enhance turfgrass stress tolerance by inhibiting the biosynthesis of gibberellins and turning on the synthesis of carotenoids that have antioxidant properties (Shell et al. 2012). Such a protection from not only biotic but also from abiotic winter damage by fungicide application in the late fall warrant further attention from Scandinavian researchers.

In conclusion, although it was unfortunate that most of the turf died due the tough winter conditions, we think this experiment yielded useful information about the prospects of using Transition under Scandinavian climate conditions. It was never expected that colorant could replace the use of fungicides, and although the experiment showed a significant effect on turf color and overall impression in November, the lack of an effect on soil temperature, combined with the relatively short longevity of the turf color and the lacking effect on turfgrass winter survival or spring recovery prevents us from making a general recommendation of the product on Scandinavian putting greens. Because of the special winter conditions in 2012-13, we suggest that the evaluation continues for another year, either on the same experimental green or on an adjacent green with a turf cover of creeping bentgrass that is now available for evaluation of turfgrass products.

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